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Quantum-efficiency measurements using HORIBA spectrometers and detectors

Evaluation of Novel Photoresponsive Materials via EQE Measurements

Introduction

Internal Quantum Efficiency (IQE) and External Quantum Efficiency (EQE) measurements are indicators of the effectiveness of a photosensitive device such as those used in telecommunications and solar cells. EQE is the ratio of the charges generated to the total amount of photons incident on the surface; a larger EQE indicates a more efficient device. IQE is the ratio of the charges generated to the number of photons that hit the surface and are absorbed by the cell. Both EQE and IQE measurements are vital in the interrogation of light-responsive devices.[1–3]

Experiment

Photosensitive devices are studied using a variety of techniques, including scanning electron microscopy, electroluminescence (EL), and photoluminescence. A typical experimental setup for measuring the EQE of a device under test is pictured in Fig. 1. A white-light source (in this case, a tungsten-halogen lamp) is coupled to a HORIBA iHR550 imaging spectrometer, producing monochromatic light. The light output is then modulated using a mechanical chopper (HORIBA ACH-C or ACH-C-OPEN), and then the light strikes the sample. The voltage output from the sample is then measured using a Stanford Research Systems lock-in amplifier, which synchronizes the chopper frequency with the modulated signal. In addition, the number of photons generated at the output is measured using a calibrated photodiode to calculate a final EQE percentage (not shown).[1,2]

EQE of thin-film solar cell

EQE spectra of organic photovoltaic cells were carried out at the Tokyo Institute of Technology. In this experiment, an iHR550 with a 100 W halogen lamp created monochromatic light, which was passed through a chopper to the sample, a thin film of zinc octaethylporphyrin. Two measurements were made: one with an amorphous sample, and another in which the film was annealed at 473 K for one minute. As seen in Fig. 2, the annealed sample shows an overall increase across the entire range, with the biggest enhancement at ~400 nm. This enhancement is attributed to increased mobility of the charge carriers within the crystalline film.[1]

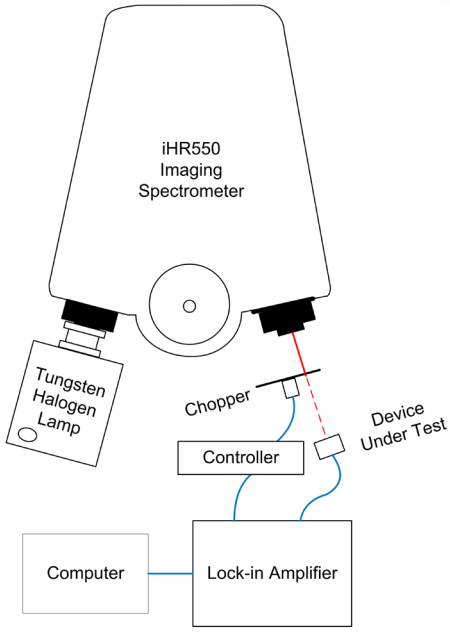

Fig. 1. Typical EQE experiment.

EQE of InAs nanowires

A second study came from the University of California–San Diego in the fabrication and testing of InAs wires. Here a halogen lamp and iHR550 were used to create monochromatic light, which was subsequently chopped and focused onto the

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sample. EQE results are shown in Fig. 3 for both the visible and infrared region in the sample, which was comprised of n-type InAs nanowires and a p-type Si substrate. The region of absorption below ~1200 nm was attributed to both InAs and Si, while only the InAs nanowires contribute above 1200 nm.[2]

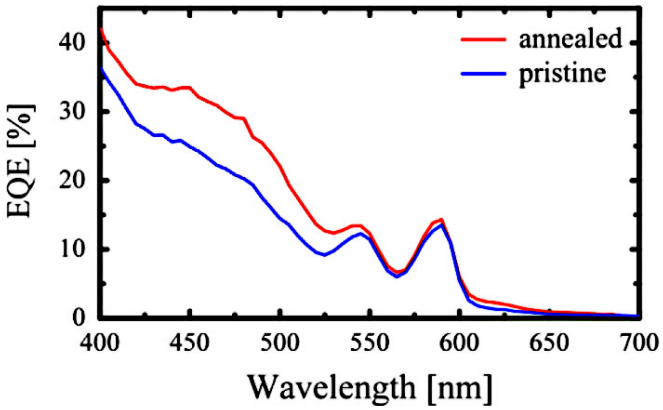

Fig. 2. EQE spectra of amorphous and annealed Zn(OEP) films. Reprinted with permission from reference 1. Copyright 2013 Sou Ryuzaki and Jun Onoe.

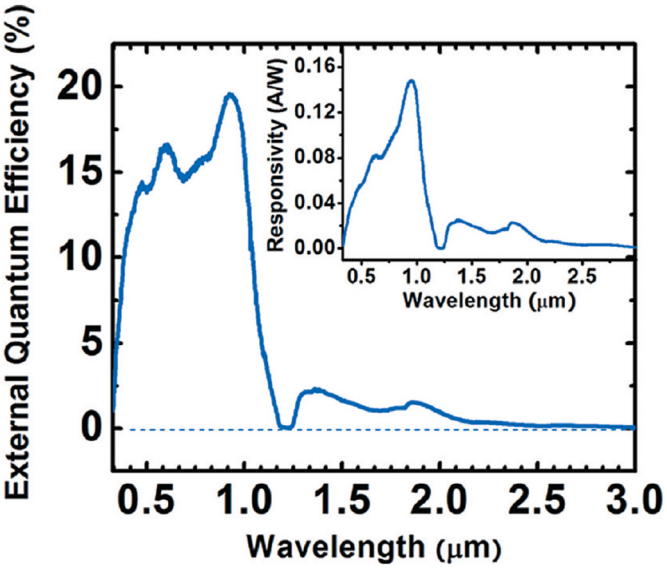

Fig. 3. EQE of n-InAs nanowires on p-Si substrate. Reprinted with permission from reference 2. Copyright 2009 American Chemical Society.

EQE and IQE of PbS nanocrystals

Finally, EQE of electroluminescent samples of PbS nanocrystals, emitting in the near-infrared, were characterized at the Nano-Electronics Centre at the University of Surrey. The EL spectra were recorded using an iHR550 and Symphony InGaAs 512-element array and a Symphony 1024 × 512 CCD, depending upon the wavelength region of interest. Integrated EL measurements were carried out to attain EQE values with an InGaAs integrating sphere. The EQE was measured as a function of voltage applied to the sample, and found to be ~1%. The IQE was estimated from transmission measurements to be between 5% and 12%. These values indicate a highly efficient near-IR emitting device, which would be valuable in a variety of systems, including biosensing and optical circuits.[3]

Conclusions

EQE measurements are an important indicator of the effectiveness of photosensitive devices. Three such studies carried out with HORIBA instrumentation are summarized herein. These studies have strong implications for a variety of applications including solar cell research and telecommunications.

References

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